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Performance Assessment of Crisis Management Plans with the Contribution of multi-agent Systems

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Crisis management aims to implement precautions of anticipation, vigilance and intervention to meet the targets. It is based on a specific tool called “crisis cell” also based on Crisis Management Plans. Crisis Management Plans are formalized in order to provide to the organizations a structured tool, where the staff involved into the crisis cell can find information and procedures. Usually, the Crisis Management Plans are tested with the preparation of exercises that can involve the Industries, the Civil Protection and the Municipalities. The improvements of these plans are based on the feedback experience from real or simulated events. However, the study of feedback experience according to real crisis show these plans do not guarantee an optimal performance of crisis cells and crisis management process. Crisis cells may become particularly weak and unable to fulfil their missions according to their own points of vulnerability. This fact underlines the importance of the implementation of a comprehensive approach for decision making, particularly on indicators performance ensuring an effective management of emergencies in terms of space and time. In this context, the authors aim to assess the organizational performance of a crisis cell, which can be considered as a complex system. This performance is based on the four main factors that must be assessed: i) The organizational and institutional factors: the complexity of the organizational network ii) The technical and resource factors: the type of infrastructure dedicated to crisis management iii) The time factors iv) The knowledge and skill factors: past experience crises, the level of preparation, the inability to effectively use the alert and communication equipments. The methodology developed is primarily based on systems thinking. The systemic approach aims to understand and simulate the operations of the crisis management, including the interactions between actors which are complex. This model describes the functions and resources of communal safeguard plan. It represents an approach particularly suited to understand the behaviour of a system. This model is also applied to give a formal reflection frame in order to analyze the potential failures of the crisis cell. The proposed methodology includes five steps: systemic exploration, qualitative modelling, dynamic modelling, simulation and risk analysis. This methodology was chosen for several reasons. Firstly, systemic exploration and qualitative modelling aim to understand and to analyze the complexity of a system, set goals and avoid mistakes in decision-making. UML (Unified Modelling Language) will be used to modelling the crisis cell. Secondly, a system to be effective, must know how to react in the time and in the complexity. Dynamic modelling is used to model and simulate the system to deal with the unexpected. MAS (Multi Agent System) were chosen to modelling dynamically the system. This analysis will propose recommendations to the studied organization for improving the organizational structure of the crisis. This methodology is a decision support toolbox that can be used to help the managerial decisions and / or guide decision-making processes in organized systems.

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1. Introduction

The word crisis comes from the Greek word “krisis” means “decision”. It was originally used in the field of medicine and then expanded in the field of psychology, politics and economics. According to Morin, the notion of crisis has spread to all areas (Morin, 1977) but remains the sudden and intense appearance of certain rupture phenomena. In 2004, the French state established a legislation to modernize the civil defence to organize and manage crises (Bill to modernize the civil security, Senate, N°277). This law allows a municipality to establish a crisis cell to protect people and safeguard the environment. However, these plans do not guarantee optimal performance of crisis units. Crisis cells may become particularly vulnerable, and unable to fulfil their missions according to the event. Questions concerning the management of crisis begin to emerge, for instance: What are the concerns of crisis management? How to manage a crisis? Which tools support the decision? Who are the main actors involved? Is the complexity of the territory a hindrance for decision-making in a risky situation?
The estimation of the decision’s consequences in a risky situation will be delicate because of the complexity of urban land in question (physical structure, networks, etc.) and environment on which these decisions must be taken. This fact underlines the importance of the implementation of a comprehensive approach for decision making, particularly on indicators ensuring an effective management of emergencies in terms of space and time.
The objective of this paper is to present a methodology for the analysis of the vulnerability of the crisis cell and assess the performance of crisis management at the municipal level. This article is structured in four sections: The first part aims to define the crisis management cell and its organization. The general principles and experiences of crisis cell will be described here through a bibliographic state of the art. The second part is devoted to describe the methodology to assess the performance of the crisis management cell based upon three main steps: the modelling of the organization with UML (Unified Modelling Language); the use of MAS (Multi-Agent Systems) in order to simulate the interactions between the different elements of the organization; the vulnerability assessment of the crisis cell. The third part underlines the contribution of MAS in order to simulate the crisis cell’s behaviour in order to assess its performance. The last section will present the expected results and the conclusion of the article.

2. Crisis management at municipality level

Crisis is defined as a loss of controlling the situation. According to Marguin (2002), crisis occurs in an environment which is composed of multiple actors who interact in the context of organized structures. The French state, based on the definition above-cited, has established a set of disposal to avoid an event generating a crisis. As a result, crisis management is a set of tools and techniques that are in place to enable an organization to cope with a crisis and be able to manage better. The law of modernization of civil security (2004) insures the protection of people by developing a culture of preparedness for risk and threat. It focuses primarily on addressing the risks by anticipating the reshaping of "protecting people" and the mobilization of all available means (Dautun, 2007). Therefore decrees have been introduced, asking for the implementation of the plan of “Organization of Civil Security Response” (ORSEC), “Communal Information Document on Major Risks” (DICRIM), and “the Municipal Plan for Safeguard” (PCS), etc.
The PCS is a document for managing a crisis in municipalities. This document will be discussed in more detail because it describes the stages of communal crisis management as well as the organization of the crisis cell. It is addressed to the mayor and aims to establish an organization in the occurrence of serious events to protect the population and the environment. The mayor is responsible for the civil protection in the commune. He has the control of police power, the responsibility to develop the PCS and to be in charge of the crisis cell. This plan is used by the mayor or his designated representative and aims to establish the communal crisis cell in order to support the civil security in the critical phase of the crisis, to restart the city as soon as possible and to manage crises. The crisis cell defines the conduct of operations and controls all operational phases such as information, support, rehabilitation, logistics, communications, general services and the switchboard. The cell can be initiated by the Mayor or upon the request of the prefectural authority. These means will permit the

organizations to establish a network of response structures supporting the coordination of actors (Dautun, 2007).
In a crisis situation many partners (fire men, police, etc.) should interact with the crisis cell in order to resolve the problem. Their coordination in this context is a major challenge for the resolution of the crisis and their interoperability is a critical component for a successful resolution. PCS is one of the few documents describing the organization at the municipal level. It implements an organization planned in advance in case of occurrence of serious events to safeguard the public and protect the environment.
The following section focuses on the methodology to assess the performance of the crisis management organization.

3. Methodology to assess the crisis management performance

The proposed approach to develop the analysis of the vulnerability of PCS's organisation based on systemic approach. It is organized in the following divisions:

- The first phase of the systemic approach (observation) allows knowing the organization of the crisis cell, the actors involved and the flows between them. Thus a visit in the studied city was necessary for the identification of crisis actors who have influence on other actors or the instability factors. Each actor is characterized by its own goals, means and constraints and by its links with other actors (Marguin, 2002).This phase involves analyzing the PCS and visit the town under study.
- From these observations, two models will be offered: the crisis cell as prescribed and as observed. After validation of both models by stakeholders, a comparison will be made to "see" if there is a difference between the two. If a difference exists between these two models, would it be related to the organization of the crisis cell? After having modelled the crisis to understand the system, we study the quality of organization by Risk Analysis. Risk Analysis will be modelled with Primarily Risk, or fault tree and UML sequence diagram.
- Risk analysis allows building scenarios. Scenarios are developed to evaluate the system in different situations. Risk analysis is the study that determines the degree of risk and assesses the direct and indirect, tangible and intangible event on an organization (Garbolino et al., 2010).
- The fourth phase of the systemic approach is to integrate the concept of time in the qualitative model to observe changes in the system. In the dynamic simulation for common applications, two modelling methodologies exist: the System Dynamics (SD) and Multi-Agent System (MAS). MAS is a collection of autonomous agents that can interact freely with each other. It is used in complex systems where artificial entities and/or natural interact to produce collective behaviour (Muller, 2005). System Dynamics proposes to study, to model and simulate the phenomena that make a change through time. Models allow us understanding the dynamics of systems based on the concepts of interaction, feedback and complexity (Forrester, 1961). MAS is focusing on individuals unlike the SD which is used for strategic modelling. One of these methodologies with theory of organization will be chosen for dynamic modelling
- The above step allows identifying vulnerabilities of the organization.
- Finally a mode of organization will be proposed

In the following section, we present the contribution of the MAS in order to assess the crisis cell's performance.

4. Contribution of multi-agent systems to simulate the crisis cell behavior

The simulation aims to analyze the properties of theoretical models of the real world in order to try to explain and predict natural phenomena. The multi-agents systems bring a solution by offering the opportunity to represent individuals, their behaviours and interactions. The multi-agent simulation is, in electronic form, the behaviour of individual entities whose interactions reveal new phenomena (i.e.

emergence). An MAS is defined as "A network of coupled problem solvers that interact to solve problems beyond individual capabilities (Durfee and Lesser, 1989). These problem solvers are often called "agents" they are autonomous and they can be heterogeneous in nature." (Kebair and Serin, 2009). MAS are entities that interact to produce a collective behaviour. One of the interesting features is the ability to reproduce the behaviour to solve a problem. The goal of SMA is to distribute the complexity of multiple agents to solve problems. So, there are two main elements to consider: the agents and their interactions.

In our study,

Each agent in this simulation is considered as a sub crisis cell. The behaviour of an agent is described by a set of rules. A rule is a set of behaviours:

$$R = (nameR;\ priorityR;\ tasksR) \quad (1)$$

where

$$tasksR = \{ t0R, \ldots, tnt\ R \}$$

$$nt = \text{number of tasks}$$

A role can be defined as a set rules:

$$role = (name;\ priority;\ KP;\ KE;\ KS;\ rules) \quad (2)$$

where

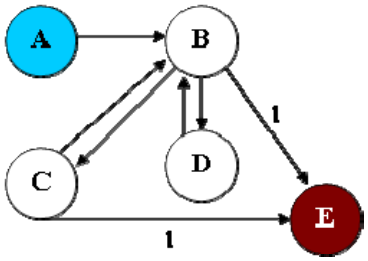
KP : Pre-requirement, consequences, weight,

KE : Environmental Knowledge (data)

KS: Social Knowledge (roles names and constraints) (Adam and Mandiau, 2007)

The figures below illustrate the behaviour of each agent. Agents have internal states and goals and act to achieve a goal. "The state of an agent is the set of significant characters for describing both its current situation and to predict future behaviour. All these characters will be represented by a form: the form known as behavioural" (Cardon, 2004). In this example, three agents are described: the Pilot/Co-pilot, the Information cell and Anticipation/Evaluation cell. Each agent has an initial state and final state .

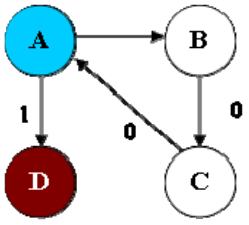
The Pilot/Co-Pilot Agent:



A: Activation of the crisis cell
B: Transfer of information to the other cells
C: Reception of external information
D: Reception of internal information
E: end – the agent stops

Figure 1: Behavior of the Pilot/Co-pilot Agent

Information and Evaluation-Anticipation Agents:



A: Message reception
B: Information treatment
C: Messages sending
D: end – the agent stops

Figure 2: Behavior of the Information and Evaluation-Anticipation Agents

To assess organizational performance in the crisis cell, each agent is associated with performance indicators. The indicators are considered as measures: they are usually sets of information used on a regular basis in order to measure changes. They can use quantitative information (raw data, comparable numbers) and qualitative information (opinions, values, yes / no). The most useful indicators for our research are those that measure the key risk areas and provide information that can explain the origin of significant problems (TOMM, 2006).
The performance indicators taken into account in our research are those that are in relation with the organizational factors of the safety. They were selected among a set of papers and the observation and interview sessions with the stakeholders. These performance indicators are the followings:

- Team mobilization: This indicator will track the number of persons present in each cell. Each cell consists of a number of people. These actors may be present or not depending on the type of crisis, or they can be unable to go to the crisis cell.
- Means: it details the resources available during the activation of the Crisis. As for the mobilization of personal, each cell has its own means to intervene in a crisis. During a crisis some means may be unavailable, or they are used in another location or they are down
- Duration of engagement: gives the duration of the presence of a cell during the crisis.
- Completeness of information: The quality of information is not related to the amount of information. There is theoretically an optimum amount of information. In addition, crisis management the flow of information is the central decision-making. The quality of the information is related to the person who receives it and the person who sends, but it is related to the level of stress, the affinity between the agents etc.
- Ability of the cell: the ability of the crisis cell indicates whether the cell is qualified and competent. Each player has the qualifications and skills but in this work we assume the whole group has the same ability. The ability is measured by the training level of the actors. Training increases the performance of the organization of the cell because the training can lead actors to acquire reflexes and get to know each other.
- Communication: this indicator provides information about the degree of communication between two cells. Communication as the quality of information is very important in crisis management. The chain of internal communication is the issue, receipt and collecting of messages. In a communication, several parameters are considered such as shared values, the level of confidence and finally listening. (Donjean, 2006). Communication takes place through several means: the means written (mails, etc.) by oral route (phone directly) and audiovisual. The lack of communication in crisis management emphasizes the fragility of the organization.
- Cohesion of the group: this indicator is based on the motivations, emotions, and common values of a cell. The more cohesive is a group, the more the organization will be effective and efficient.
- Time analysis of the information: time analysis of information is limited (Pateyron, 1988). The time analysis of the information is the time interval between when the cell receives the information and the time it sends the information. The response time includes the time required to retrieve the information and analysis of information. The time analysis of the information takes into account the stress level of the agents, the availability of resources. Fatigue in a crisis, is the first enemy of clarity and cohesion of the group.
- Moral of the team: this parameter may be affected during a crisis and can affect the performance of the organization. Team motivation can boost the group to better manage the crisis. This motivation will impact the group cohesion.
- Hazard: this indicator is characterized by its probability of occurrence and intensity. Depending on the intensity of the phenomenon, the organization will not react in the same way. In fact, if the hazard is low the actors in the crisis will be less stressed and more effective decision making.

The qualification and quantification of each indicator performance will be completed with the stakeholders by using interviews and observations during training sessions. The state of the art in this domain will also complete the filed observations.
All of these performance indicators will be integrated into the MAS platform in order to simulate their interactions and to understand the behavior of the whole crisis cell. The results of the simulations will give information according to scenarios of organizational failures. These results will be useful in order to propose organizational barriers dedicated to the crisis cell organization. A set of recommendations and of organizational strategies will be provided and validated by the stakeholders.

5. Conclusion

Because our socio-technical systems depend to both technical and organizational factors, it is significant to identify the potential failures of our organizations. In the case of crisis cell, which is a very particular organization, the performance of this kind of organization is a key point to assess. Usually, this assessment is base on feedback experience of real situations or training sessions. In this paper, the authors propose a repeatable methodology, base on artificial intelligence, in order to assess the performance of crisis cells. This methodology takes into account the model of the organization and simulates the behavior of its components by the use of Multi Agents Systems. This methodology is still under development and will carry its first results in the beginning of 2012. The results will bring new information in order to identify the potential organizational failures and to propose barriers and way of re-organization of the crisis cell.

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